SCHIZOPHRENIC PERFORMANCE ON A MENTAL ROTATION TASK

A thesis presented to the

Department of Psychology

University of Canterbury

In partial fulfilment of the

requirements for the degree of

Master of Arts in Psychology

---

by

Christopher Alan Howison

March, 1982

ACKNOWLEDGEMENTS

The author wishes to thank all those who were involved in this thesis, with special gratitude to my supervisor and mentor, Mr Paul Russell.

I would also like to thank Dr J.A. Begg and Mr H.R. Unger for their kind permission to carry out research at Sunnyside Hospital, and Mrs M. Beekhuis for her help in obtaining subjects. Thanks are also due to Mr N. Blampied for making his slide projector available, and all those who served as subjects in this research.

Finally, to my wife Jill, and daughter Sarah, thank you for your understanding and help throughout this undertaking.

ABSTRACT

The response times of 16 schizophrenic, and 16 non-hospitalized normal controls were compared on a task which required subjects to identify the normal or mirror image version of letters presented at different orientations. The gradient of the reaction time function increased with angular separation of normal letter stimuli from upright, for both groups, but was steeper for schizophrenics, suggesting that they mentally rotate these stimuli at a slower rate than normals. Results did not show these characteristics for backward letters, but were similar for both groups. Results are discussed with reference to studies of required rotational transformations in schizophrenics.

CONTENTS

CHAPTER I

INTRODUCTION

This thesis examines the ability of schizophrenic subjects to perform mental transformations on the orientation of simple visual forms. It is based on the work of Cooper and Shepard (1973) and uses reaction time (RT) methods. It also relates to early psychometrically based studies of rotational disturbances in patients with organic mental and schizophrenic disorders.

A number of standardized tests, used in ascertaining the presence of brain damage have required the short term retention and then reproduction of visual forms, (Bender, 1938; Benton, 1963; Canter, 1970; Fuller and Laird, 1963). In these tests the reproduced forms are required to be figurally identical, but either at the same or different orientations to the originals, and are scored in terms of the number or magnitude of rotations. Results are not unequivocal, but where rotation was not required, spontaneous rotations tend to be more common where there is known brain pathology (Royer and Holland, 1975, a, pp 846-7).

Similarly, comparisons of schizophrenic and organically mentally disordered groups are far from definitive, but where controls for age, intelligence and education have been present, it has been found that process schizophrenics in particular, also have a tendency to produce spontaneous rotations. (Watson, 1968; Holland and Wadsworth, 1974; Holland, Wadsworth and Royer, 1975; Watson, Gasser, Schaefer, Buranen and Wold, 1981). The results from studies employing inadequate controls are confusing. One reports a tendency for schizophrenics to spontaneously rotate (George, 1973) while others do not (Crookes, 1978; Freed, 1969; Griffith and Taylor, 1960).

Studies of required rotation of visual designs have shown process and reactive schizophrenics to be similar to normals and different from organically mentally disordered subjects, who experience difficulty volitionally producing rotations (Royer and Holland, 1975,b). Haydu and Rutsky (1966) produced similar results using chronic schizophrenics, while Satz (1966) found that normal, neurotic, and schizophrenic subjects performed at comparable levels on a Block Rotation Test.

Overall, these studies have produced equivocal results, contain many methodological deficiencies and are often not clearly related to theoretical explanations of rotational transformations (Satz, 1966; Shapiro, 1953). So, in line with Broen's (1968) contention that progress in understanding processing in psychopathology depends on advances in our basic knowledge about processes in normal persons, one strategy for research is to focus on data that can be clearly related to aspects of sensory, perceptual or cognitive processing that are already well established with normals. (Kietzman, Spring and Zubin, 1980). The mental rotation paradigm (Cooper and Shepard, 1978) meets this requirement and offers a recent information processing model with which to explore required rotational transformations in schizophrenics.

Based on the early work of Shepard and Metzler (1971) and two experiments by Shepard and Klun, Cooper and Shepard (1973) presented asymmetrical alphanumeric characters to their subjects at six equally spaced orientations from zero through to 360 degrees. Alphanumeric stimuli consisted of either an uppercase normal or mirror image (backward) version. The subjects task was to discriminate the normal from the backward version of the same character, regardless of their orientation within the picture plane. This requirement was imposed to force the subjects to "mentally rotate" all the test characters before comparing them to their normal upright representation, presumably stored in long term memory.

Reaction time was found to be a monotonically increasing function of the angular separation of the rotated test stimulus from the standard upright orientation. Cooper and Shepard explained these results in terms of an information processing model consisting of six processing stages: (1) character identification which possibly occurs prior to; (2) the determination of orientation; (3) an imagined character rotated into the upright orientation; (4) comparison of the mentally upright representation with the "template" for the character produced from long term memory; (5) response selection and finally; (6) response production.

They provided further evidence of mental rotation in the above study in which the identity of the stimulus was first given, followed by a cue indicating it's orientation, and then the stimulus. Increasing the duration of the orientation of the cue resulted in a progressive decrease of latency orientation slope functions. When the orientation cue was 1 sec, RT was the same for all orientations, just as it was when the task involved the comparision of 2 physically present forms at the same orientation. These results suggested that in the cueing condition subjects had performed a preparatory rotation prior to target stimulus presentation and had in effect by-passed process 3 of the above model.

A large number of studies using alphabetic and alpha-numeric characters, animal pictures and angular forms (Childs and Polich, 1979; Cooper, 1975; Cohen, 1975; Marmor, 1977; Petrusic, Varro and Jamieson, 1978; Tapley and Bryden, 1977; White, 1980) have replicated the basic finding of a monotonic increase in RT with orientational separation from upright, although it is not entirely clear at this stage just what the defining features of rotational stimuli are (Cooper and Podgorny, 1976; Hochberg and Gellman, 1977; Pylyshyn, 1979), nor what representational processes are involved, (Anderson, 1978; Cooper and Shepard, 1978, Kosslyn and Pomerantz, 1977; Paivio, 1976; Pylyshyn, 1973). Nevertheless it is generally accepted that the model outlined above is at least a good first approximation of the processes involved when alphabetic stimuli are used. Therefore, in order to clarify our understanding of the ability of schizophrenics to perform spatial transformations of objects, the performance of a group of schizophrenics and normal control subjects were compared using the basic Cooper and Shepard mental rotation task.

CHAPTER II

THE EXPERIMENT

EXPERIMENTAL DESIGN

Subjects were required to identify uppercase letters as either normal or mirror image (backward) versions by responding "yes" if it was a normal and "no" if it was a backward version. This is essentially similar to Cooper and Shepard's (1973) no information condition; except that stimulus set, response mode, and presentation display differed.

A four factor design was used with repeated measures on three factors. The factors were: (1) groups at two levels, i.e. a schizophrenic and normal control group; (2) letter type at three levels, i.e. letters F, G, and R; (3) letter version at two levels, i.e. normal or backward, and (4) angle of orientation at six levels, i.e. 0, 60, 120, 180, 240, 300 degrees.

1. STIMULI

Stimuli consisted of the three uppercase, typewritten Courier 10 font letters F, G and R, and their backward versions. The letters (white on a black background) were projected onto a screen approximately 60 centimeters distant from the subjects eyes and measured 2.8 cm high (visual angle 2.67°) and 2.5 cm wide (visual angle 2.39°).

Seven identical slides of each letter at each of the six orientations, 0^{o} through to 300^{o}, for both normal and mirror image conditions were prepared. They were arranged in random order in seven blocks of thirty six slides covering the full range of letter, decision, and orientation conditions. The same ordering was used for all subjects, the first two blocks of seventy two slides served as practice.

2. APPARATUS

A Kodak Carousel projector model SAV-2000 with a Kodak VAR-10 Retinar 70-120 zoom lens was used to back project the stimuli onto a translucent screen. A Lafayette electrically operated shutter (Model 43011-16) placed in front of the projector was connected to a Sanyo (Model FS-81) foot switch which was pressed down by the subjects preferred hand. This initiated, after a 0.5 second delay, (controlled by a Lafayette four bank timer, Model 52011) the projection of a slide onto the screen, while simultaneously starting a Lafayette clock counter (Model 54517) which registered the reaction time to the nearest millisecond. The slide display and clock stayed on until the subject spoke into the microphone which was connected to a Lafayette voice activated relay (Model 1604A). This response terminated the slide display and stopped the clock. The sensitivity of the voice activated relay was adjusted during practice trials to suit each subject, although in practice it was rarely necessary to alter levels.

After each stimulus presentation the experimenter pressed a reset button which moved the carousel onto the next slide. Both the experimenter and experimental apparatus were screened from the subjects view by white hardboard screens, set at an angle of approximately 45 degrees on either side of the display screen, on the table behind which the subject sat.

3. PROCEDURE

All subjects were tested in the Psychology Department at Sunnyside Hospital. Prior to beginning the experiment proper the subjects were taken behind the display screen and shown the experimental apparatus. A simple explanation of how the equipment operated along with their role in its functioning was given. After this the subject was asked to sit down in front of the screen with the experimenter taking a seat beside him/her. The instructions were then read to the subjects. They were;

> "In front of you is a screen onto which will appear one of three letters, an F, a G, or an R when you press this pad. Sometimes the letter will be normal (at this point three 7 cm by 8 cm cards, each displaying one normal letter at 0 degrees were presented), and sometimes it will be a backward letter (cards with the backward letter were placed beside their corresponding normals). I have taken these letters and moved them around so that some of them are the right way up but most of them are not (the normal and backward letters were separated and a rotated example of each letter was placed next to its upright counterpart). I want you to tell me as quickly as you can whether the letter is a normal F, G, or R (experimenter pointed to all the normal letters) by saying "yes" into the microphone, or if it is a backward F, G, or R (experimenter points to all the backward letters) by saying "no" into the microphone. When you say "yes" or "no" the letter will disappear from the screen. After you hear me change the projector to the next letter you may press the pad whenever you are ready and the next letter will appear. Try not to move your head to either left or right when each letter appears. Be as quick and as accurate as you can when saying "yes"

> or "no" to each letter. Have you any questions?"

It was then explained to the subject that;

> "I am going to give you some practise at this. If you make a mistake I will tell you so you can project that letter back up onto the screen and see where you went wrong. Have you any questions?"

The experimenter then retired behind the screen to operate the slide change and to record the results.

After the 72 practise trials were completed the subject was told that:

> "This time I will not tell you whether you are right or wrong. Just do your best and remember to be as quick and as accurate as you can in saying "yes" or "no" to each letter. Have you any questions?"

As the slides were housed in four carousels, subjects were allowed approximately a one minute rest period when carousels were changed. After subjects had completed all trials once, the experimental trials on which there had been errors were readministered in consecutive order until each subject performed a correct response to all 180 trials.

The duration of experimental sessions ranged from 45 to 60 minutes, and was then followed by the administration of Jastak and Jastak's (1964) shortened form of the Wechsler Adult Intelligence Scale vocabulary subtest.

4. SUBJECTS DETAILS

Demographic characteristics of the subject groups are given in Table 1

(i) Schizophrenic Sample

The sample of sixteen patients tested was drawn from two admission wards and one rehabilitation ward at Sunnyside Hospital, Christchurch, during November and December of 1980, and January, June and August of 1981. They were selected on the basis of psychiatrist's diagnosis, case histories and clinical psychologists's observations. The diagnosis of schizophrenia was confirmed using the criteria specified by Astrachan, Harrow, Adler, Bauer, Schwartz, Schwartz and Tucker (1972) in the New Haven Schizophrenia Index.

Patients included in this study were not receiving electro-convulsive therapy, and had no secondary diagnosis such as alcoholism, epilepsy or mental retardation. Patients diagnosed as schizo affective, who were acutely disturbed at the time of selection or who had organic or suspected organic etiology were also excluded from the study.

Of the subjects finally selected for testing, one was subsequently eliminated because she was so acutely disturbed that she could not perform the task, while two others refused to participate in the experiment.

(ii) Control Sample

A sample of sixteen non-psychiatric, non-institutionalized subjects was drawn from the general population and were individually matched to schizophrenic subjects for sex, age, verbal intelligence and educational status.

TABLE 1

Subject Demographic Data

	Schizophrenics	Controls
Age		
Mean	25.17	25.61
S.D.	4.18	4.44
WAIS Vocabulary		
Mean	11.37	11.25
S.D.	2.09	2.17
Education (Years Secondary/Tertiary)		
Mean	3.84	3.86
S.D.	1.71	1.62
Sex (frequency)		
Male	14	14
Female	2	2
NHSI[1]		
Range	5-10	
Mean	7.56	
Previous Admissions		
Range	0-6	
Median	1	
Current Hospitalization in weeks		
Range	3-103	
Median	10	
P.D.I.[2] (mgm/day)		
Range	0-4357	
Median	1000	

1. N.H.S.I. = New Haven Schizophrenia Index
2. P.D.I. = Phenothiazine drug index (Hollister, 1970), measuring daily drug intake of patients in terms of a daily equivalent of chlorpromazine.

CHAPTER III

RESULTS

1. ERRORS

The percentage error, that is, the number of errors expressed as a percentage of the total errors pooled over groups and letters, for each orientation, and each version are presented in Table 2. Errors are too few to analyze statistically, but general trends indicate that although schizophrenics make more errors, both groups have generally low error rates with errors increasing with angle of orientation for both groups in the normal letter condition.

2. RESPONSE TIMES

The median of the correct RT's for each subject in each letter, version and orientation condition was found. Medians were used in preference to means in order to reduce the effects of extreme noncharacteristic responses.

Group means pooled over letters were then found and are displayed in Figure 1. This indicates that RT increased monotonically with orientational difference from upright for the normal stimuli, but the relationship of RT to orientation is not straight forward in the case of backward letters.

These data were treated by a groups x letters x versions x orientation analysis of variance. No three or four way interactions were significant. However, the versions x orientation effect was significant,

$F(5, 150) = 6.10$, $p<0.001$. Consequently, separate groups x letters x orientations ANOVA's were performed on the normal and backward letter data.

All analyses of variance were computed using the Biomedical Statistical Package BMD 08V program.

The variability of RT's of each group in each condition is indicated in Table 3. This table reports the variance pooled over the three letters in each condition. These variances tend to be greater for schizophrenics, and for both groups to be positively correlated with RT for letters in their normal version.

3. REACTION TIMES FOR NORMAL LETTERS

For normal letter data the groups x orientation x letter analysis revealed that the interactions of letters and orientation, $F(10, 300) = 1.94$, $p<0.05$, and groups, letters and orientation $F(10, 300) = 2.21$, $p<0.025$, were significant. However for both groups, and all letters RT increased monotonically with orientational difference from upright. The effect of orientational difference was greater for "R", and especially so for schizophrenics. Because all letters displayed the same monotonic increasing effect, and because these interactional effects are small (variance components, Vaughan and Corballis, 1969, of 1112 and 868.8 m sec respectively for the groups x letters x orientation, and letters x orientation effects), subsequent discussion of the normal version data will refer to effects pooled over letters.

Figure 1 indicates that schizophrenics responded more slowly than controls to normal letters, that the RT of both groups increased with orientational difference from upright, and that the effect of orientation was greater for schizophrenics. So, following Cooper and Shepard (1973) and others (Kail, Carter and Pellegrino, 1979, Kail, Pelligrino and Carter, 1980) it is argued that RT's can be partitioned into (1) the processes of performing a "mental rotation" and (2) of completing the various encoding, comparison, response and other non-rotational processes. Rate of rotation is reflected in the gradient of the RT orientation function, while the time required for encoding, comparison, response and other processes are reflected in the absolute value of the RT's in the upright (0 degree orientation) condition since this involves no rotation. Hence the following analyses address the question as to whether schizophrenics differ from normal controls in their speed of mental rotation, and in completing the encoding, comparison, response and other processes.

In the above analysis, the groups x orientation effect was significant, $F(5, 150) = 3.7$, $p<0.01$, therefore the rate of increase in RT with orientational difference from upright was greater for schizophrenics. This suggests that schizophrenics rotate at a slower rate than controls.

Analysis of the data for each group separately indicates that the orientational effect was significant for each group: schizophrenics, $F(5, 75) = 13.16$, $p<0.001$; controls, $F(5, 75) = 16.86$, $p<0.001$. The variance components for the orientation effect for schizophrenics was 54, 117.6 m sec and for controls was 10,407.3 m sec. This clearly demonstrates that controls rotated at a faster rate, around

474 degrees per second, than schizophrenics who rotated at around 205 degrees per second.

When no rotation was involved as in the upright condition, schizophrenic RT's exceeded those of the controls by 580.4 m sec and this difference was significant, $F(1,30) = 18.52$, $p<0.001$. Therefore, schizophrenics also required more time than controls to complete encoding, comparison, response and other non-rotational processes.

4. REACTION TIMES FOR BACKWARD LETTERS

As for the above, analyses were pooled over letters. The letters x orientation interaction was significant, $F(10, 300) = 2.21$, $p<0.025$, but the groups x letter x orientation effect was not significant, so no separate analyses of orientational effect for each group is needed. All letters displayed the "W" like pattern displayed in Figure 1, with the centre 180 degree peak being less pronounced for "G".

When pooled over letters the orientation main effect was significant, $F(5, 150) = 3.92$, $p<0.01$, and overall "R" was responded to the fastest, and "G" the slowest. Groups also differed, $F(1, 30) = 9.02$, $p<0.01$ with the schizophrenics being some 630.7 m sec slower than the controls. No other effects were significant, and in particular the groups x orientation effect was not significant.

TABLE 2

Percent error in each letter

and orientation for each group

(1) Normal letter version

	ORIENTATION						
	0°	60°	120°	180°	240°	300°	Total
Controls	1.23	1.64	5.51	11.44	2.44	0.41	3.94
Schizophrenics	0.00	0.83	8.05	17.24	2.83	2.04	5.57

(2) Backward letter version

	ORIENTATION						
	0°	60°	120°	180°	240°	300°	Total
Controls	3.61	1.23	0.83	6.61	1.64	0.83	2.51
Schizophrenics	3.23	2.04	2.04	6.61	0.41	5.51	3.36

TABLE 3

Group variances (pooled over letters) for normal and backward versions at each orientation

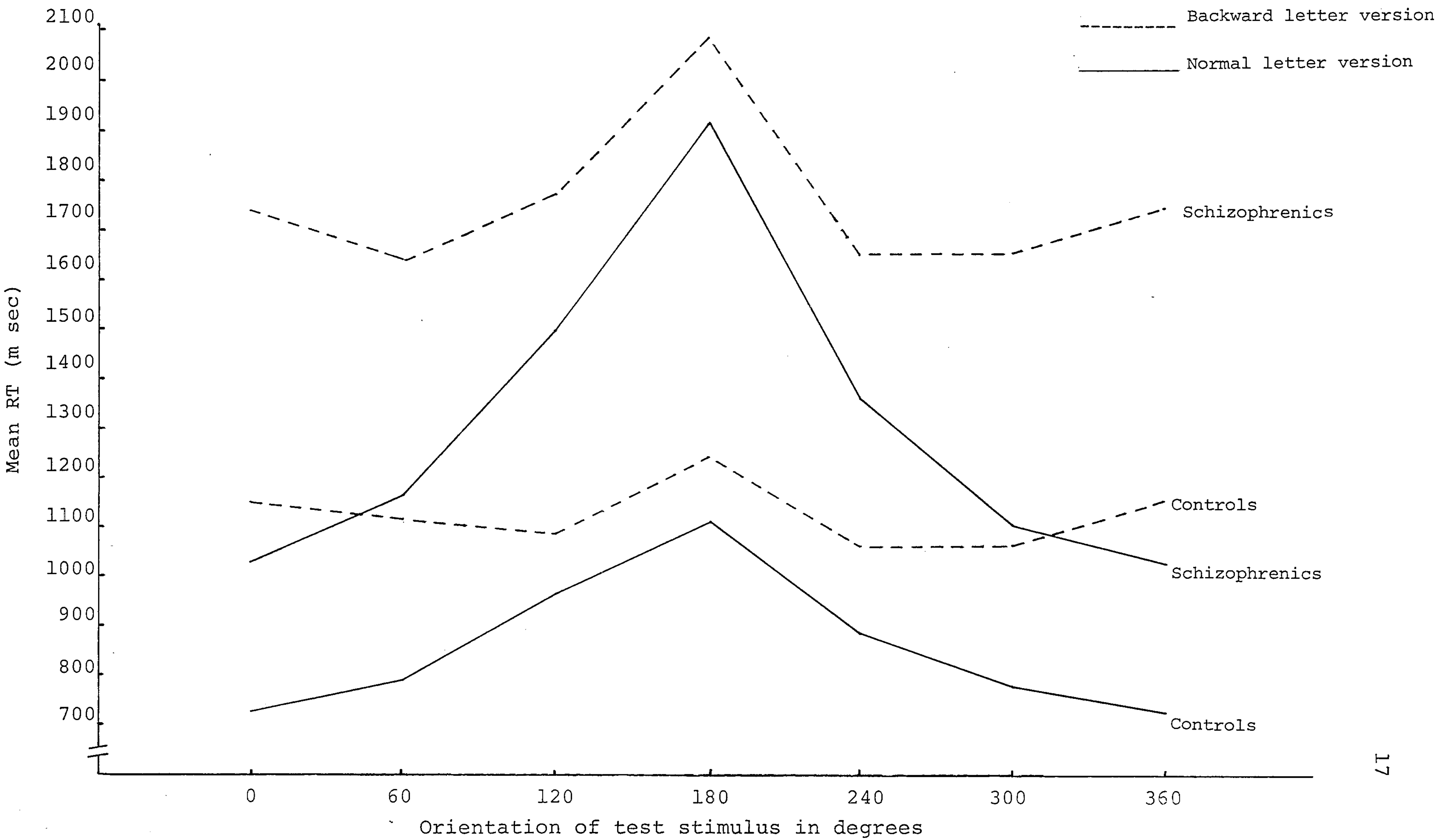
(1) Normal letter version

	ORIENTATION					
	0°	60°	120°	180°	240°	300°
Controls	3.12	5.03	8.74	6.80	4.13	4.06
Schizophrenics	5.52	6.98	15.73	19.88	12.64	5.67

(2) Backward letter version

	ORIENTATION					
	0°	60°	120°	180°	240°	300°
Controls	9.84	10.06	7.99	5.00	4.53	7.49
Schizophrenics	21.25	13.89	14.57	31.89	13.18	16.91

Figure 1: Mean response time (in m sec) of groups for normal and backward letters at various orientations (in degrees clockwise from upright).



CHAPTER IV

DISCUSSION

The major findings of this study were that response times of both groups increased monotonically with angular separation for letters in their normal, but not backward versions, that for normal letters the rate of increase in response time with angular difference from upright was slower for schizophrenics than control subjects, and that the response times of schizophrenics were greater for normal letters in an upright condition.

An interpretation of these results in terms of the processing stage model proposed by Cooper and Shepard (1973) and outlined in the introduction, is complicated by the distinctly different RT-orientation functions obtained for normal and backward letters.

While the majority of studies report similiar functions for normal and backward versions (Carpenter and Eisenberg, 1978; Cooper and Shepard, 1973; Corballis, Zbrodoff and Roldan, 1976; Hock and Tromley, 1978; Kail, Carter and Pellegrino, 1979; White, 1980), it is not clear in some studies (Child and Polich, 1979; Young, Palef and Logan, 1980) whether the results from backward and normal versions were ever separately examined. Therefore it may not be correct to assume that because no mention of separate RT-orientation functions was made, that none existed.

At least two studies using line drawn stimuli (Hochberg and Gellman, 1977) and perspective drawings

(Gaylord and March, 1975) have obtained dissimilar results for backward versions. Hockberg and Gellman (1977) explained their results in terms of a variable mix of strategies and processes being used by their subjects, while Gaylord and March (1975) thought it reflected unsuccessful attempts at rotation.

A number of relatively simple explanations such as voiced versus key press response (Carpenter and Eisenberg, 1978; Corballis, Zbrodoff and Roldan, 1976) small number of letter stimuli (Carpenter and Eisenberg, 1978; Childs and Polich, 1979; Young, Palef and Logan, 1980), and head movements by subjects (Corballis, Zbrodoff and Roldan, 1976) appear to be ruled out. The effects of different letter types have not been explored in the literature.

One possible explanation stems from studies of eye fixations found to reflect the sequence of mental operations occurring during mental rotation (Carpenter and Just, 1978; Just and Carpenter, 1976). These authors were able to specify three distinct stages involving, (1) search, (2) transformation and comparison, and (3) confirmation. For single letter stimuli Carpenter and Just (1978) found the search stage to be non existent or of very brief duration when the entire letter can be encoded in foveal or parafoveal vision. The durations for the transformation and comparison stages increased monotonically with the angular separation of letters from upright. The confirmation stage, indicated by rescanning the figure after fixation of the critical feature, may therefore have made a major contribution to the "V" shaped functions obtained in the range up to 120^{o} either side of the upright.

As Carpenter and Just (1978) combined their results for the normal and backward "J", their findings do not apply directly to the results of this study. However their findings lend support to the argument that when the more unfamiliar backward versions are to be processed, more time was spent by both groups on confirming the correctness of an initial reaction, which may have thereby contributed to the "V" shaped RT-orientation functions obtained for backward letters. Indeed, evidence of this confirmation process was seen for both groups of subjects, who, throughout this experiment continually vocally corrected errors made after an incorrect response had terminated the letter display.

Another explanation involves the suggestion of Cooper and Shepard (1973) that a 'template' match, similar to that found by Posner, Boies, Eichelman and Taylor (1969) for physical letter matches, occurs after the letter is mentally rotated. Posner (1978) using the horse race model of the matching process (Posner, 1975) argued that if the physical code of a letter was extended over time by mental rotation so that it was of longer duration than the process involved in producing the letter name, interference may be produced between the physical and phonetic codes.

This prediction is supported by Buggie (1970) who found that when one of two simultaneously presented letters was rotated, that where the subject was required to respond same to physically indentical letter pairs, those that had the same name took longer than those without the same name.

Perhaps backward letters, which have been found to have response times some 50-471 m sec more than their normal version counterparts (Cooper and Shepard, 1973; Corballis, Zbrodoff, and Roldan, 1976; Hock and Tromley, 1978; White, 1980), produce optimal conditions for the phonetic code to produce interference with the physical match, and thereby produce irregular results under certain experimental conditions.

However for the normal letter version the mental rotation paradigm fits the data better than any other model and so is appropriate for the study of schizophrenic cognitive deficit (Neufeld and Broga, 1981), as has been found for other special populations (Arnold, 1978; Borys, 1980; Carpenter and Eisenberg, 1978; Gaylord and Marsh, 1975; Marmor and Zaback, 1976). Schizophrenics mentally rotated these normal letter stimuli at a slower rate than control subjects, their estimated rate of rotation being 205^{o}/sec and 474^{o}/sec respectively. Rate of rotation for normal controls was comparable to that obtained by Cooper and Shepard (1973) and Corballis, Zbrodoff and Roldan (1976), while Young, Palef and Logan (1980) found rotation rates lying almost half way between this study and those of Kail, Pellegrino and Carters' (1980) study, which were half the rate found here.

Although schizophrenics produced more errors in this condition than controls, speed accuracy trade off (Pachella, 1974), cannot account for the speed of rotation difference obtained between groups. According to speed accuracy trade off theory the results obtained overestimate the speed at which schizophrenics in particular mentally rotate. Indeed overall error rates are similar for both groups to those obtained in other studies which range from 3% to 8.2%

(Cooper and Shepard, 1973; Kail, Carter and Pellegrino, 1979; Hock and Tromley, 1978; White, 1980).

This study therefore confirms the findings of psychometric and other studies involving required rotation (Royer and Holland, 1975 b; Haydu and Rutsky, 1966; Satz, 1966), which show that schizophrenics have the ability to produce required rotations of visually presented stimuli, but adds further that the rate at which they do this is somewhat slower, at least for familiar stimuli not transformed by a back to front reflection.

The difference in RT of the upright condition between controls and schizophrenics is difficult to interpret, as it may be due to any or all of the processes specified in Cooper and Shepards (1973) model, excluding that of mental rotation. Therefore, all that can be definitively concluded from this is that schizophrenics are also slower in the combination of non-rotational processes involved in the task.

REFERENCES

ANDERSON, J.R. Arguments concerning representations for mental imagery. Psychological Review, 1978, 85, 249-277.

ARNOLD, P. Mental rotation by deaf and hearing children. Perceptual and Motor Skills, 1978, 47, 977-978.

ASTRACHAN, B.M., HARROW, M., ADLER, D., BAUER, A., SCHWARTZ, A., SCHWARTZ, C., and TUCKER, G. A checklist for the diagnosis of schizophrenia. British Journal of Psychiatry, 1972, 121, 529-541.

BENDER, L.G. Visual Motor Gestalt test and its clinical use. American Orthopsychiatric Association Research Monograph, 1938, 3.

BENTON, A.L. The revised Visual Retention Test: Clinical and experimental applications. (3rd ed.). Iowa City: The State University of Iowa, 1963.

BORYS, S.V. Kinetic imagery ability of mentally retarted young adults. American Journal of Mental Deficiency, 1980, 84, 582-588.

BROEN, W.E. Schizophrenia: Research and Theory, Academic Press, New York, 1968.

BUGGIE, S. Stimulus preprocessing and abstraction in the recognition of disoriented forms. In Posner, M.I. Chronometric Explorations of Mind. The Third Paul M. Fitts Lectures. Hillside, N.J.: Erlbaum Associates, 1978, 40-41.

CANTER, A. The Canter Background Interference Procedure for the Bender Gestalt Test Manual for administration, scoring and interpretation. Iowa City. Iowa Psychopathic Hospital, 1970.

CARPENTER, P.A., and EISENBERG, P. Mental rotation and the frame of reference in blind and sighted individuals. Perception and Psychophysics, 1978, 23, 117-124.

CARPENTER, P.A., and JUST, M.A. Eye fixations during mental rotation. In Senders, J.W., Fisher, D.F., and Monty, R.A. (Eds). Eye Movements and the Higher Psychological Functions. Hillsdale, N.J.: Erlbaum Associates, 1978, 115-133.

CHILDS, M.K., and POLICH, J.M. Developmental differences in mental rotation. Journal of Experimental Child Psychology, 1979, 27, 339-351.

COHEN, G. Hemispheric differences in the utilization of advance information. In Rabbitt, P.M.A., and Dornic, S. (Eds). Attention and Performance V, New York, Academic Press, 1975, 20-32.

COOPER, L.A. Mental rotation of random two-dimensional shapes. Cognitive Psychology, 1975, 7, 20-43.

COOPER, L.A., and PODGORNY, P. Mental transformations and visual comparison processes: Effects of complexity and similarity. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 503-514.

COOPER, L.A., and SHEPARD, R.N. Chronometric studies of the rotation of mental images. In Chase, W.G. (Ed) Visual Information processing. New York: Academic Press, 1973, 76-176.

CORBALLIS, M.C., ZBRODOFF, J., and ROLDAN, C.E. What's up in mental rotation? Perception and Psychophysics, 1976, 19, 525-530.

CROOKES, T.G. Factors in the rotation of reproduced figures. Journal of Clinical Psychology, 1978, 34, 446-449.

FREED, E.X. Actuarial data on Bender-Gestalt test rotations by psychiatric patients. Journal of Clinical Psychology, 1969, 25, 252-255.

FULLER, G.B., and LAIRD, J.T. The M.P.D. Test. Journal of Clinical Psychology, 1963, 16, 1-33. (Monograph Supplement).

GAYLORD, S.A., and MARSH, G.R. Age differences in the speed of a spatial cognitive process. Journal of Gerontology, 1975, 30, 674-678.

GEORGE, J. Differentiating clinical groups by means of the Minnesota Percepto-Diagnostic Test. Journal of Clinical Psychology, 1973, 29, 210-212.

GRIFFITH, R.M., and TAYLOR, V.H. Incidence of Bender-Gestalt figure rotations. Journal of Consulting Psychology, 1960, 24, 189-190.

HAYDU, G.G., and RUTSKY, A. Figure reversing ability in Chronic brain syndrome and controls. The Journal of Nervous and Mental Diseases, 1966, 142, 168-171.

HOCHBERG, J., and GELLMAN, L. The effect of landmark features on mental rotation times. Memory and Cognition, 1977, 5, 23-26.

HOCK, H.S. and TROMLEY, C.L. Mental rotation and perceptual uprightness. Perception and Psychophysics, 1978, 24, 529-533.

HOLLAND, T.R., and WADSWORTH, H.M. Incidence versus degrees of rotation on the Minnesota Percepto-Diagnostic test in brain damaged and schizophrenic patients. Perceptual and Motor Skills, 1974, 38, 131-134.

HOLLAND, T.R., WADSWORTH, H.M., and ROYER, F.L. The performance of brain-damaged and schizophrenic patients on the Minnesota Percepto-Diagnostic test under standard and BIP conditions of administration. Journal of Clinical Psychology, 1975, 31, 21-25.

HOLLISTER, L.E. Choice of Antipsychotic drugs. American Journal of Psychiatry, 1970, 127, 186-190.

JASTAK, J.F., and JASTAK, S.R. Short forms of the WAIS and WISC vocabulary subtests. Journal of Clinical Psychology, 1964, 20, 167-199. (Monograph).

JUST, M.A., and CARPENTER, P.A. Eye fixations and cognitive processes. Cognitive Psychology, 1976, 8, 441-480.

KAIL, R., CARTER, P., and PELLEGRINO, J. The locus of sex differences in spatial ability. Perception and Psychophysics, 1979, 26, 182-186.

KAIL, R., PELLEGRINO, J., and CARTER, P. Developmental changes in mental rotation. Journal of Experimental Child Psychology, 1980, 29, 102-116.

KIETZMAN, M.L., SPRING, B., and ZUBIN, J. Perception, cognition, and attention. In Kaplan, H.I., Freedman, A.M., and Sadock, B.J., (Eds). Comprehensive Textbook of Psychiatry, ed 3, Williams and Wilkins, Baltimore, 1980, 334-371.

KOSSLYN, S.M., and POMERANTZ, J.R. Imagery, propositions, and the form of internal representations. Cognitive Psychology, 1977, 2, 52-76.

MARMOR, G.S. Mental rotation and number conservation: Are they related? Developmental Psychology, 1977, 13, 320-325.

MARMOR, G.S., and ZABACK, L.A. Mental rotation by the Blind: Does mental rotation depend on visual imagery? Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 515-521.

NEUFELD, R.W.J., and BROGA, M.I. Evaluation of information sequential aspects of Schizophrenic performance. II Research Strategies and methodological issues. The Journal of Nervous and Mental Disease, 1981, 169, 569-579.

PACHELLA, R.G. The interpretation of reaction time in information processing research. In Kantowitz, B. (Ed), Human information processing: Tutorials in Performance and Cognition. Hillside, N.J.: Erlbaum Associates, 1974.

PAIVIO, A. Images, propositions, and knowledge. In Nicholas, J.M. (Ed), Images, Perception and Knowledge. (The Western Ontario Series in the Philosophy of Science). Dordrecht, Netherlands: Reidel, 1976.

PETRUSIC, W.M., VARRO, L., and JAMIESON, D.G. Mental rotation validation of two spatial ability tests. Psychological Research, 1978, 40, 139-148.

POSNER, M.I. The temporal course of pattern recognition in the human brain. In Inbar, G.F. (Ed), Signal Analysis and Pattern Recognition in Biomedical Engineering. New York: Wiley, 1975.

POSNER, M.I. Chronometric Explorations of Mind. The Third Paul M. Fitts Lectures. Hillsdale, N.J.: Erlbaum Associates, 1978.

POSNER, M.I., BOIES, S.J., EICHELMAN, W.H., and TAYLOR, R.L. Retention of visual and name codes of single letters. Journal of Experimental Psychology, 1969, 79, 1-16.

PYLYSHYN, Z. What the mind's eye tells the mind's brain. A critique of mental imagery. Psychological Bulletin, 1973, 80, 1-24.

PYLYSHYN, Z.W. The rate of "mental rotation" of images: a test of a holistic analogue hypothesis. Memory and Cognition, 1979, 7, 19-28.

ROYER, F.L., and HOLLAND, T.R. Rotational transformation of visual figures as a clinical phenomenon. Psychological Bulletin, 1975, 82, 843-868 (a).

ROYER, F.L., and HOLLAND, T.R. Rotations of visual designs in psychopathological groups. Journal of Consulting and Clinical Psychology, 1975, 43, 546-556 (b).

SATZ, P. A block rotation task. The application of multivariate and decision theory analysis for the prediction of organic brain disorder. Psychological Monographs General and Applied, 1966, 80 (21, Whole No 629).

SHAPIRO, M.B. Experimental studies of a perceptual anomaly: III: The testing of an explanatory theory. Journal of Mental Sciences, 1953, 99, 394-409.